**An Efficient Model of Enhanced Optimization and Attention-based GCNN with GRU for Nail Disease Detection and Classification Framework**

**Introduction**

Nail diseases including fungal infections, psoriasis, and melanoma, represents a significant subset of dermatological conditions that affect a large portion of the population. Timely and accurate diagnosis of these diseases is crucial for effective treatment and management [8]. However, traditional diagnostic methods often rely on visual inspection and manual examination by trained dermatologists, which can be time-consuming and subjective, leading to variability in diagnosis and potential delays in treatment [9]. Nail diseases encompassing a variety of conditions affecting the nail and its surrounding structures, are prevalent health issues that can significantly impact an individual's quality of life [10]. The nail unit, comprising the nail plate, nail bed, matrix, cuticle, and surrounding skin, is susceptible to numerous disorders due to various factors such as infections, systemic diseases, trauma, and genetic predispositions [11]. Accurate and timely detection and classification of nail diseases are crucial for effective treatment and management, preventing potential complications and improving patient outcomes. Traditional methods of diagnosing nail diseases often rely on visual inspection and clinical expertise, which can be subjective and prone to variability [12]. In recent years, advancements in medical imaging and machine learning have opened new avenues for enhancing diagnostic accuracy and consistency. Automated detection and classification systems, leveraging image processing techniques and artificial intelligence (AI), offer promising solutions for early and precise identification of nail disorders [13].

Detecting and classifying nail diseases present a myriad of challenges due to the complexity and variability of nail disorders. The human nail, with its unique anatomical and physiological characteristics, is susceptible to a diverse range of conditions, including fungal infections, psoriasis, lichen planus, and melanonychia [14]. These diseases can manifest in various forms and severities, complicating the diagnostic process.One of the primary challenges are the visual similarity among different nail disorders. Many nail conditions share overlapping clinical features, such as discoloration, thickening, and deformities, making it difficult to distinguish between them based solely on visual inspection [15]. This complexity often necessitates the expertise of highly trained dermatologists, yet even specialists can face difficulties in achieving accurate diagnoses [16]. Additionally, the subtlety of early-stage nail disease symptoms poses a significant hurdle. Early manifestations can be minimal and easily overlooked, leading to delayed diagnosis and treatment. The subjective nature of traditional diagnostic methods further exacerbates this issue, as individual interpretations can vary widely, resulting in inconsistent and unreliable outcomes [17]. Technological limitations also play a role in the challenges faced in nail disease detection and classification. While advancements in imaging and AI hold promise, the development of robust, accurate, and generalizable models is hampered by the lack of comprehensive, high-quality datasets. Ensuring that these models are trained on diverse and representative samples is crucial for their effectiveness across different populations [18]. Addressing these challenges is essential for improving diagnostic accuracy and patient outcomes, paving the way for more effective management of nail diseases [19].

Deep learning is a subset of machine learning inspired by the structure and function of the human brain's neural networks, has emerged as a powerful tool in the field of medical image analysis [20]. In recent years, researchers have increasingly employed deep learning techniques to enhance the detection and classification of nail diseases, offering new opportunities for improving diagnostic accuracy and efficiency [21]. One of the key advantages of deep learning approaches is their ability to automatically extract relevant features from raw image data, eliminating the need for manual feature engineering [22]. This feature extraction process enables the detection of subtle abnormalities and variations in nail morphology that may be indicative of underlying diseases. Furthermore, deep learning models can learn from large datasets, allowing them to generalize well to unseen data and adapt to diverse patient populations. This capability is particularly beneficial in dermatology, where the presentation of nail diseases can vary widely among individuals [23]. Several deep learning architectures have been applied to nail disease detection and classification tasks, ranging from traditional CNNs to more advanced models such as recurrent neural networks (RNNs) and generative adversarial networks (GANs) [24]. These models can be trained on annotated image datasets, learning to distinguish between different types of nail disorders with high accuracy [25].

**Related works**

In 2023, Regin *et al.* [1] have suggested a fresh deep learning system for identifying and categorizing nail disorders from photos. CNN models (CNN) was combined in this framework to extract features. This research was also contrasted with certain other province algorithms (Support vector, ANN, K - nearest neighbors, and RF) evaluated on datasets and showed positive results.

In 2023, Mujahid *et al.* [2] have suggested to train and evaluate various deep learning models applying transfer learning for an indigenous nail melanoma localization dataset. Using the dermoscopic image datasets, seven CNN-based DL architectures (viz., VGG19, ResNet101, ResNet152V2, Xception, InceptionV3, MobileNet, and MobileNetv2) was trained and tested for the classification of skin lesions for melanoma detection. The trained models were validated, and key performance parameter (i.e., accuracy, recall, specificity, precision, and F1-score) was systematically evaluated to test the performance of each transfer learning model. The results indicated that the proposed workflow could realize and achieve more than 95% accuracy.

In 2023, Lukas *et al.* [3] have proposed to automatically quantify the modified NAPSI (mNAPSI) of patients using neuronal networks retrospectively. Firstly, we performed photographs of the hands of patients with psoriasis, psoriatic arthritis, and rheumatoid arthritis. In a second step, we collected and annotated the mNAPSI scores of 1154 nail photos. Followingly, we extracted each nail automatically using an automatic key-point-detection system. The agreement among the three readers with a Cronbach’s alpha of 94% was very high. With the nail images individually available, we trained a transformer-based neural network (BEiT) to predict the mNAPSI score.

In 2017, Marie *et al.* [4] have suggested to detect subclinical enthuses and nail abnormalities using Gray-Scale (GS) and Power Doppler Ultrasonography (PDUS) between patients with nail psoriasis and those with inverse and scalp psoriasis. Detection of subclinical US enthesopathy was not so rare in both groups, unlike PD signal, but with no statistical difference. US were a good tool to evaluate the different components of psoriatic nails (loss of trilaminar appearance, nail thickening and inflammation of the skin thickness) which was significantly associated with nail psoriasis.

In 2019, Trupti *et al.* [5] have recommended model for human fingernail image processing system, different classification techniques for nail feature classification and nail features. The nail features such as color, shape and texture used to predict diseases. Color features discussed was Mean, Standard Deviation, Skewness, Kurtosis and average RGB color. Different classification techniques such as SVM classifier, KNN classifier, ANN classification used to classify the nail database for disease prediction are discussed.

In 2017, Nijhawan *et al.* [6] have suggested a hybrid of CNNs for feature extraction. Due to the non-existence of a meticulous dataset, a new dataset was built for testing the enactment of our proposed framework. This work was tested on our dataset and has also been compared with other state-of-the-art algorithms (SVM, ANN, KNN, and RF) that have been shown to have an excelled performance in the area of feature extraction.

In 2021, Jumana *et al.* [7] have proposed deep CNN, namely (AlexNet, Vgg16, GoogleNet, ResNet50 and DenseNet201). Six metrics was calculated to evaluate the performance of each Transfer Learning (TL) model, which was accuracy, recall, specificity, precision, F-score and time. The TL models was implemented and trained based on MATLAB programming software.

In 2019, Aishwarya *et al.* [8] have recommended Visual Geometry Group (VGG)-19 for feature extraction. Due to the unavailability of a diligent dataset, a new dataset was built for testing the accuracy of our contended framework. This work has been tested on our dataset and has also been compared with other state-of-the-art algorithms (SVM, ANN, KNN, Tree, RF, Adaboost) that results in great performance in feature extraction.

**Problem Statement**

Automated systems revolutionize the early detection of nail diseases, preempting visible symptoms and enabling timely intervention. By swiftly processing vast image datasets, they expedite screening and diagnosis, proving invaluable in bustling clinical environments. Yet, despite these benefits, they also grapple with limitations. The limitations are mentioned below.

* Traditional methods often falter in detecting incipient nail conditions, particularly those concealed beneath the surface or not immediately apparent. This leads to diagnostic delays. The innovative model tackles head-on with cutting-edge deep learning methodologies.
* Accurate diagnosis traditionally demands specialized expertise, a resource not universally accessible among healthcare providers. The advanced approach bridges the gap by leveraging sophisticated techniques, less reliant on individual proficiency.
* In the traditional model, confirming diagnoses often requires invasive procedures like nail biopsies, which can cause discomfort and pose risks to patients. This evolved strategy promotes a more refined understanding and classification, while also minimizing these limitations.
* Conventional heuristic algorithms, though expedient, prioritize simplicity over optimal solutions, often sacrificing accuracy for speed. This advanced strategy avoids such trade-offs by employing nuanced techniques, ensuring both precision and computational efficiency.

Table 1 offers the challenges and features of the conventional nail disease detection and classification model.

**Table 1:** Features and challenges of deep learning based conventional nail disease detection and classification model framework

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| --- | --- | --- | --- |
| **Author [citation]** | **Methodology** | **Features** | **Challenges** |
| Regin *et al.* [1] | CNN | * It is robust to variations in input data such as different nail sizes, orientations, or lighting conditions. | * It requires a large amount of labeled data for training, which might be a limitation if sufficient annotated nail images are not available. |
| Mujahid *et al.* [2] | VGG 16 | * It allows leveraging pre-trained models trained on large datasets (like ImageNet) and fine-tuning them on a smaller dataset (such as nail images), which can mitigate the need for a vast amount of labeled data. | * It requires expertise in hyperparameter tuning and might still require a considerable amount of computational resources. |
| Lukas *et al.* [3] | nail psoriasis severity index (NAPSI) | * It ensures consistency in evaluating disease severity and treatment outcomes. | * It may not fully capture disease activity or fluctuations over time. |
| Marie *et al.* [4] | Machine Learning | * It can handle multi-class classification problems like NAPSI classification effectively. | * It requires comparing the test sample with every training sample. |
| Trupti *et al.* [5] | KNN | * It is a simple and intuitive algorithm. | * It is sensitive to irrelevant or redundant features, which might be an issue if the feature set is not well-defined or contains noise. |
| Nijhawan *et al.* [6] | CNN | * It automatically learn hierarchical representations from raw data, which is beneficial when dealing with image data | * It might be a limitation if sufficient annotated nail images are not available. |
| Jumana *et al.* [7] | TL | * It has faster convergence during training compared to training from scratch due to the pre-trained weights. | * It requires expertise in hyperparameter tuning and might still require a considerable amount of computational resources. |
| Aishwarya *et al.* [8] | VGG 16 | * It can capture rich hierarchical features from images, which is advantageous for complex classification tasks like NAPSI classification. | * The fine-tuning process is not properly regularized, especially with a limited amount of training data. |

**Research Methodology**

Nail diseases present a diverse array of conditions affecting the nails, ranging from nail psoriasis to onychomycosis (fungal nail infections), nail dystrophies, and trauma-induced changes. A primary goal of nail disease classification models is to accurately identify and categorize these various disorders by analyzing visual cues present in nail images. These automated models offer the advantage of swiftly processing large quantities of nail images, potentially expediting diagnosis and facilitating prompt intervention and treatment. However, the challenge lies in the variability of visual manifestations across different nail diseases. Many conditions share overlapping features, making it difficult for classification models to distinguish between them accurately. In response to the challenges faced by the conventional model, a novel deep learning-based classification system will be proposed. The system aims to leverage the advances in deep learning techniques to improve the accuracy and efficiency of nail disease classification. Initially, the system will be gather nail images from established benchmark datasets. These images will be serving as the input for the proposed deep learning model, named as Adaptive and Attention-based Graph Convolution Neural Network with Gated Recurrent Unit (AA-GCNN-GRU). This model will be specifically designed to effectively classify nail diseases by combining the capabilities of GCNN and GRU. The parameters of the AA-GCNN-GRU model will be optimized using the Enhanced Walrus Optimization Algorithm (EWOA). To evaluate the performance of the proposed classification system, it will be compared against several recent methods. Various performance measures will be employed to assess the accuracy, robustness, and efficiency of the system in classifying nail diseases. The architecture view of the newly designed nail disease classification system using deep learning is displayed in Figure 1.

Collection of nail images

Classification

AA-GCNN-GRU

EWOA

Final classified outcome

**Figure 1:** Diagrammatic representation of proposed nail disease classification system Model

**Expected Outcome**

The proposed nail disease classification model based on deep learning model will be implemented using the Python software, where the experimental analysis will be done to evaluate the performance of the proposed scheme. The statistical as well as convergence analysis will be done to execute the effectiveness.

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